Taylor Impact Tests and Simulations of Plastic-Bonded Explosives

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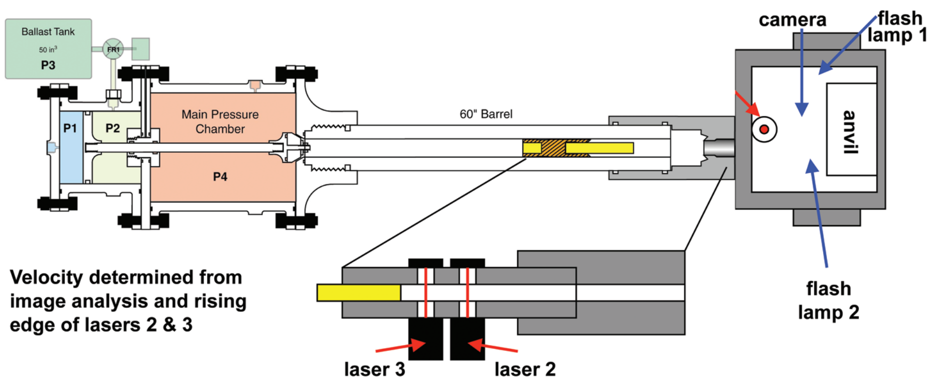
Taylor impact tests have been conducted on plastic-bonded explosives to characterize the stress state of these materials as they impact anvil surfaces at speeds between 80 and 200 m/s. Using a high-speed camera, specimen images are obtained as they undergo substantial deformation, including fragmentation. PBX 9501 and PBXN-9 are investigated. By performing finite element simulations, the Taylor test has proved to be a valuable tool for validating LANL explosives models in situations undergoing extreme damage and fragmentation.

Taylor impact tests were previously conducted on plastic-bonded explosives (PBX) to characterize the stress state of these materials as they impact smooth flat anvil surfaces at speeds on the order of 100 m/s [1]. The focus of that work was on the explosive PBXN-109. In 2003, Liu and Ellis performed Taylor tests on PBX 9501 up to speeds of 115 m/s, capturing impact images using high-speed photography [2]. The goal was to discover the threshold velocity for the initiation of the explosive. No threshold was observed. In the work presented here we extended these tests to velocities in excess of 200 m/s. We used a high-speed camera to obtain specimen images as they undergo substantial deformation, including fragmentation. PBX 9501 and PBXN-9 were investigated. While no chemical reaction was observed at these velocities, the Taylor test proved to be a valuable tool for validating LANL PBX models in situations undergoing extreme damage and fragmentation.

Fig. 1. Schematic of the Taylor impact setup used in this study.



A schematic of the experimental setup is shown in Fig. 1. An oscilloscope tracks three lasers that are mounted on a composite-lined gun barrel and in the steel box containing the anvil to trigger diagnostics and determine the projectile velocity. A Phantom 7 camera allows images to be taken at 25 s per frame. We obtained ten shots on PBX 9501 and eight on PBXN-9 for impact speeds between approximately 80 and 214 m/s. In Fig. 2, two shots at nearly the same velocity show the quality of the information achieved in these experiments. A comparison of these images shows that a different behavior is observed in the more viscoelastic PBXN-9 than in the more brittle PBX 9501. For the same impact velocity, significantly more of the PBXN-9 is consumed in the fragmentation process than is the case with PBX 9501, while the PBX 9501 fragments tend to be much finer than in PBXN-9.

The quasi-static mechanical properties of PBX 9501 (Fig. 2 shows a representative plot) and PBXN-9 have been characterized in both tension and compression. In addition, LANL researchers [3] have used the Split Hopkinson Pressure Bar (SHPB) apparatus to measure the stress-strain curves at higher strain rates. This data (Fig. 3) is used to calibrate LANL's ViscoSCRAM explosives constitutive model. Together with ViscoSCRAM's shear crack-growth, a simple tensile failure condition that acts at the finite-element (FE) level has been added. The FE code ABAQUS is used to simulate the Taylor tests. The tensile failure condition used states that when an element is in hydrostatic tension and the principal tensile strain exceeds a specified value, the element will permanently cease to support a load. Using this technique, fragmentation was simulated. At early times (see Fig. 4) ViscoSCRAM

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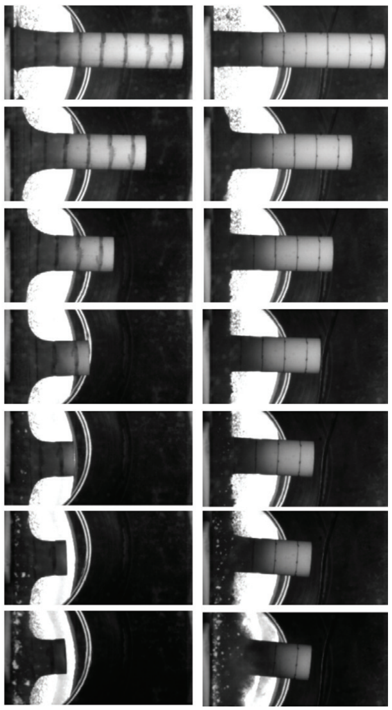
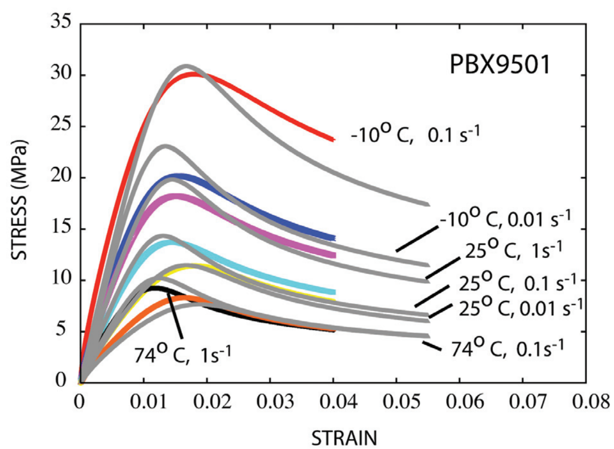


Fig. 2. PBXN-9 Taylor tests at a velocity of 136.6 m/s (left), and PBX 9501 at a velocity of 132.1 m/s (right). Each frame is 100 m/s in succession, with the first frame shown being at the instant of impact and the final frame being near the conclusion of the deformation.

performed well, but at later times, the element death technique gave poor results, presumably attributable to the lack of fragment-fragment interactions. This work is to be viewed as a first step in modeling Taylor experiments.

Fig. 3. Low-rate uniaxial compression experiment and ViscoSCRAM model fits to PBX 9501 stress-strain curves. The theory curves are the longer ones.



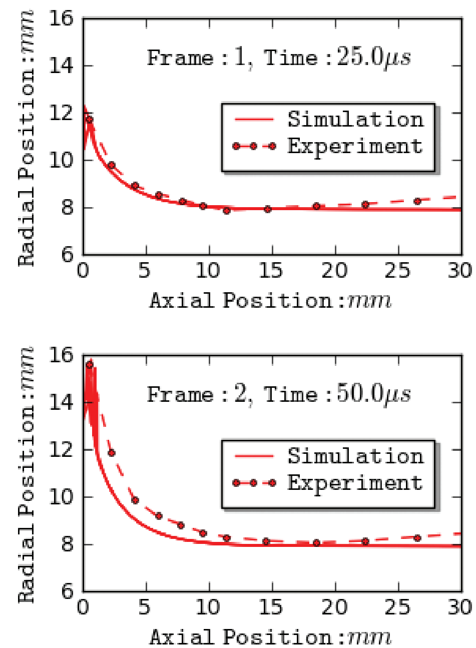


Fig. 4. PBXN-9 136 m/s experiment and simulated cylinder profiles at 25 and 50 ms. At 50 ms, the jagged simulation profile between 14 and 16 mm occurs due to fragmentation. A critical tensile strain of unity was used.

[1] Christopher, F.R. et al., *Proc 11th Int Detonation Symp* **286** (1998).
[2] Liu, C. and R. Ellis, LANL (unpublished).
[3] Gray, G.T. III et al., *Proc 11th Int Detonation Sym* **76** (1998).

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